Team Six:
Autonomous Aerial Vehicle
Final Presentation

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Discussion Topics

Abstract

Design Concepts

Simulations

Test Flight
- Mechanics
- Autopilot
- Demonstration

Budget

Environmental Analysis

Conclusions

Future Recommendations

General Remarks

Abstract

Design and test for AUVSI competition

- Image analysis
- Autonomous navigation
- Air drop
- Target detection

"Designing for the Future"

- ASME competition showcasing the capstone projects of undergraduate students
- 30 slide technical presentation
- Finalists featured at the International Design Engineering Technical Conference (IDTEC)

Manual for future Seniors

- Progress toward competition goals
- Parts available in Team Six design office
- Challenges faced and lessons learned

Competition Requirements

Competition divided into primary and secondary objectives

- Primary objectives state minimum requirements to compete
- Secondary objectives are voluntary and add to overall score

Primary

- Autonomous navigation
- Survey area for targets
  - Requires onboard camera with live video transmission

Secondary

- Autonomous target recognition
- Off-axis target identification
- Emergent target detection
- Simulated remote information center
- Interoperability
- Infrared target location
- Payload delivery system

Decision Matrix

Objective	Competition Priorities	Cost	Difficulty	Required Time	Risk	Totals
Autonomous Flight	10	10	8	9	5	**42**
Buy New Aircraft	6	4	9	9	10	**38**
Modify Old Airplane	4	8	6	6	4	**28**
Retractable Landing Gear	2	6	6	5	6	**25**
Glass Camera Door	3	9	8	9	9	**38**
Retractable Camera Door/Gimbal System	9	5	5	3	6	**28**
Infrared Camera	7	0	5	7	0	**19**
Modular Design	3	7	4	4	5	**23**
Autonomous Takeoff/Landing	7	9	5	6	3	**30**
Autopilot System Training	2	7	3	3	8	**23**
Autonomous Target Recognition	7	9	3	3	8	**30**
Air Drop System	7	6	6	7	8	**34**

Airframe Decision

Helicopter vs Quadcopter vs Fixed wing

- Stability
- Flight duration
- Autonomous navigation

Inherited airframe vs New model

- Fuselage will not require repairs before modification and implementation of new equipment
- Flaps are desirable in autonomous takeoff and landing
  - Increased lift, stable at low speeds
- New airframe came with electric motor
  - More reliable, environmentally friendly, and easier to operate/maintain
- Old airframe used for low risk flight practice and equipment testing

Air Drop System – Design

Two-door approach

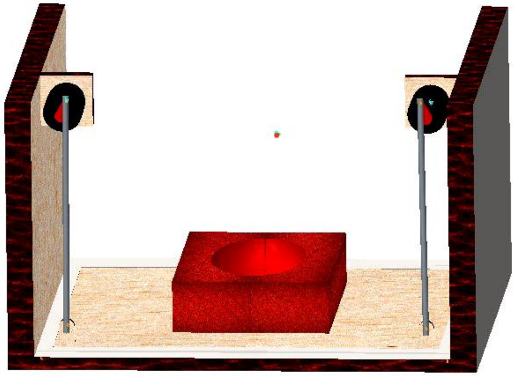
- Minimize air resistance when bay doors are open
- Minimize additional horizontal velocity components on release
- Cut doors from existing plane body

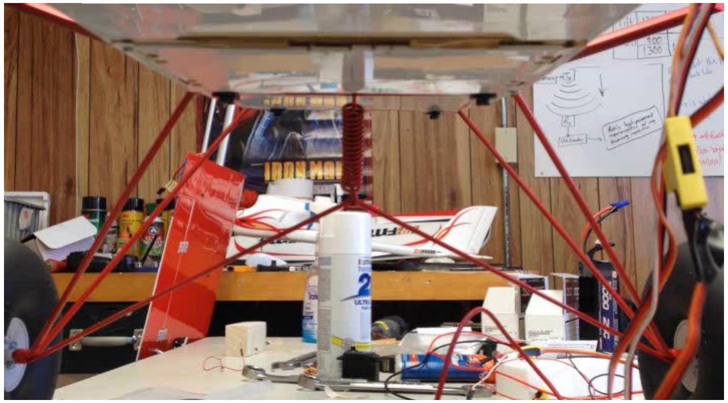
Basic four-bar linkage to engage doors

- Controlled with two servos

Securing the payload

- Cut from foam material
  - Provides cushioning
- Will compress, allowing doors to fully open





Camera – GoPro vs SD Camera

Sample target size (blue doors): 6x8ft

Target distance: 100ft

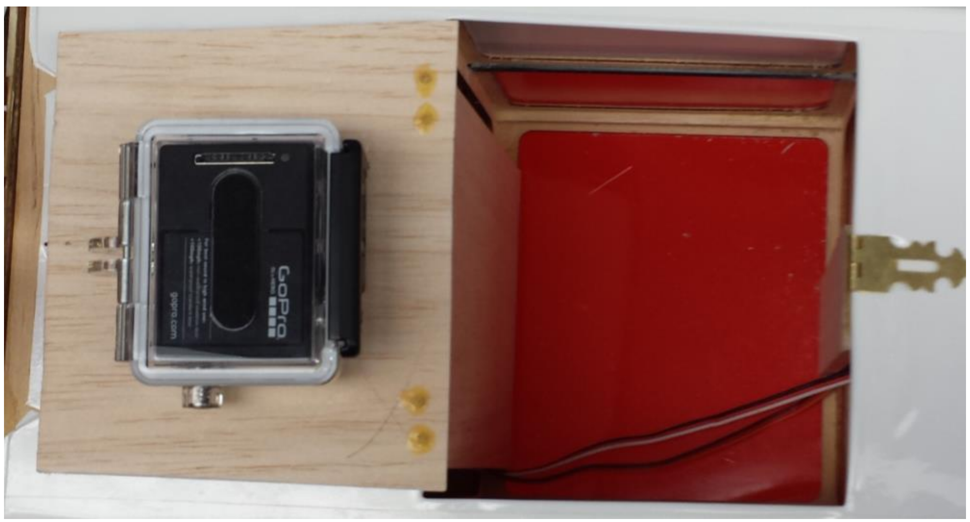
Significant difference in resolution, aspect, and color

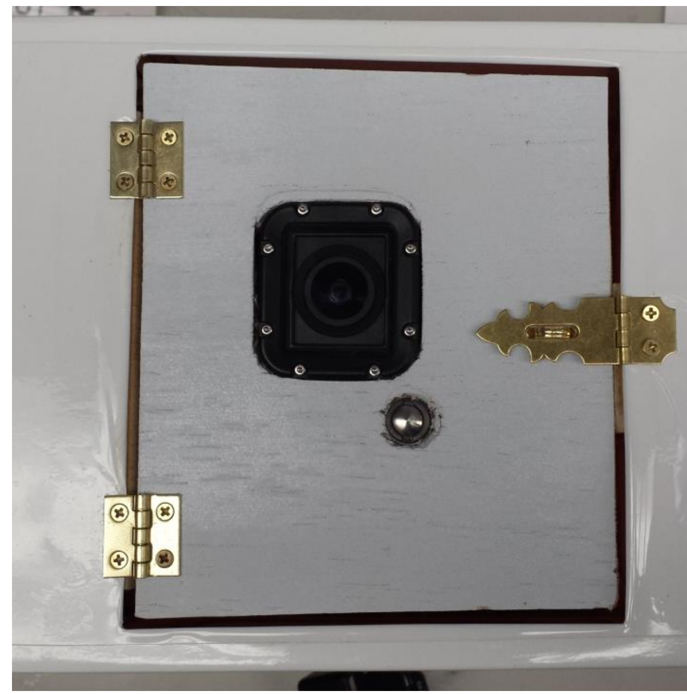
Digital vs Analog
- Increased resolution and bandwidth
- Digital signals less susceptible to noise

GoPro

KT&C

Camera Mounting

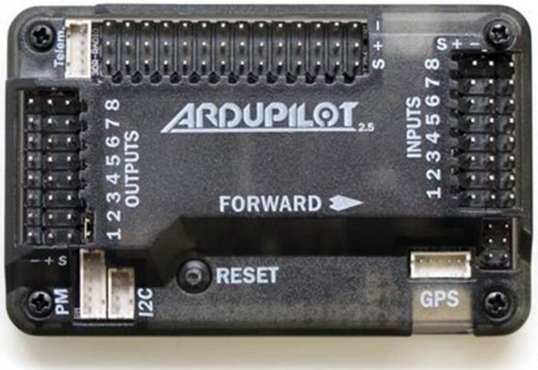




Autopilot System

ArduPilot Mega 2.5

- Inherited from previous year ($200+ saved)
- Features
  - Onboard
    - Gyrometer, accelerometer, compass, magnetometer
  - External
    - Global positioning (GPS), telemetry radio, airspeed sensors
  - Support hardware-in-the-loop testing with flight simulator
- Supported by Mission Planner
  - Open source, GUI-based waypoint mission planner
  - Able to reprogram ArduPilot in-flight
    - Secondary competition objective
  - Built-in support for autonomous takeoff and landing



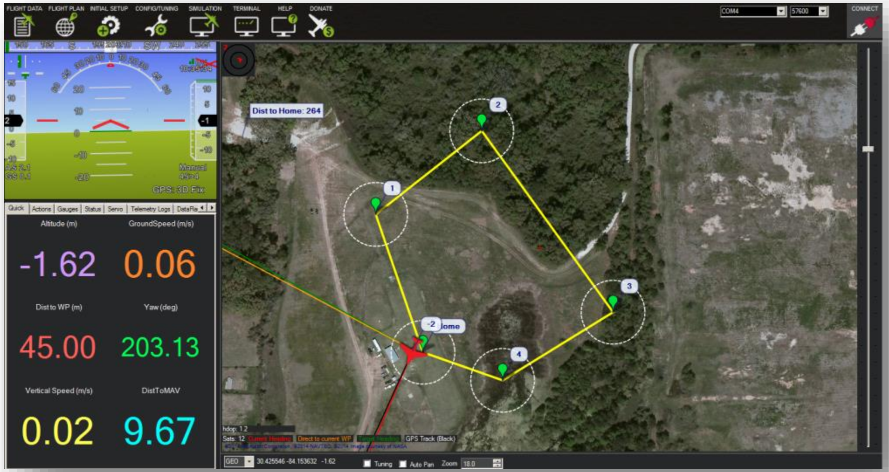
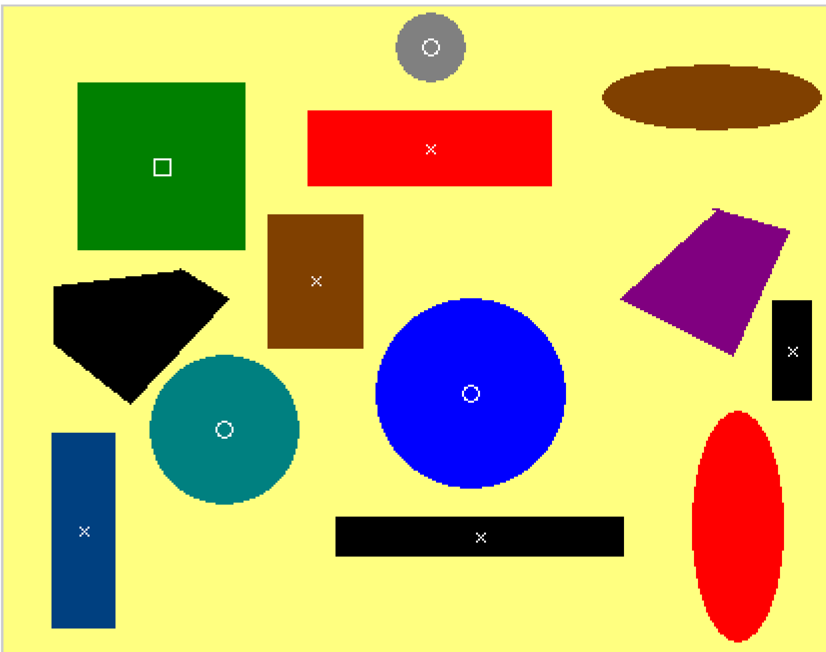
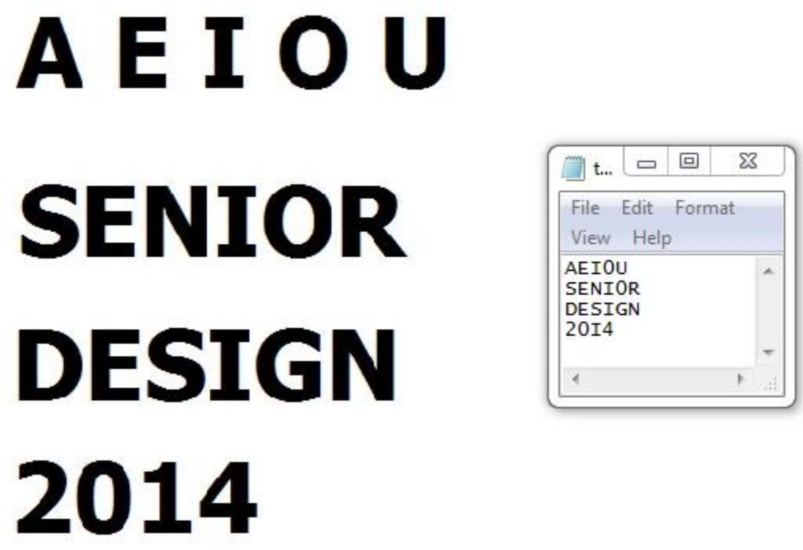


Image Processing





Matlab

- Image Processing Toolbox, Image Acquisition Toolbox, Neural Network Toolbox

Prototype Specifications

Senior Telemaster Plus

- Total Weight: $9lb$
- Wingspan: $94\ in$
- Length: $64\ in$
- Wing Area: $1330\ in^2$

Battery Packs

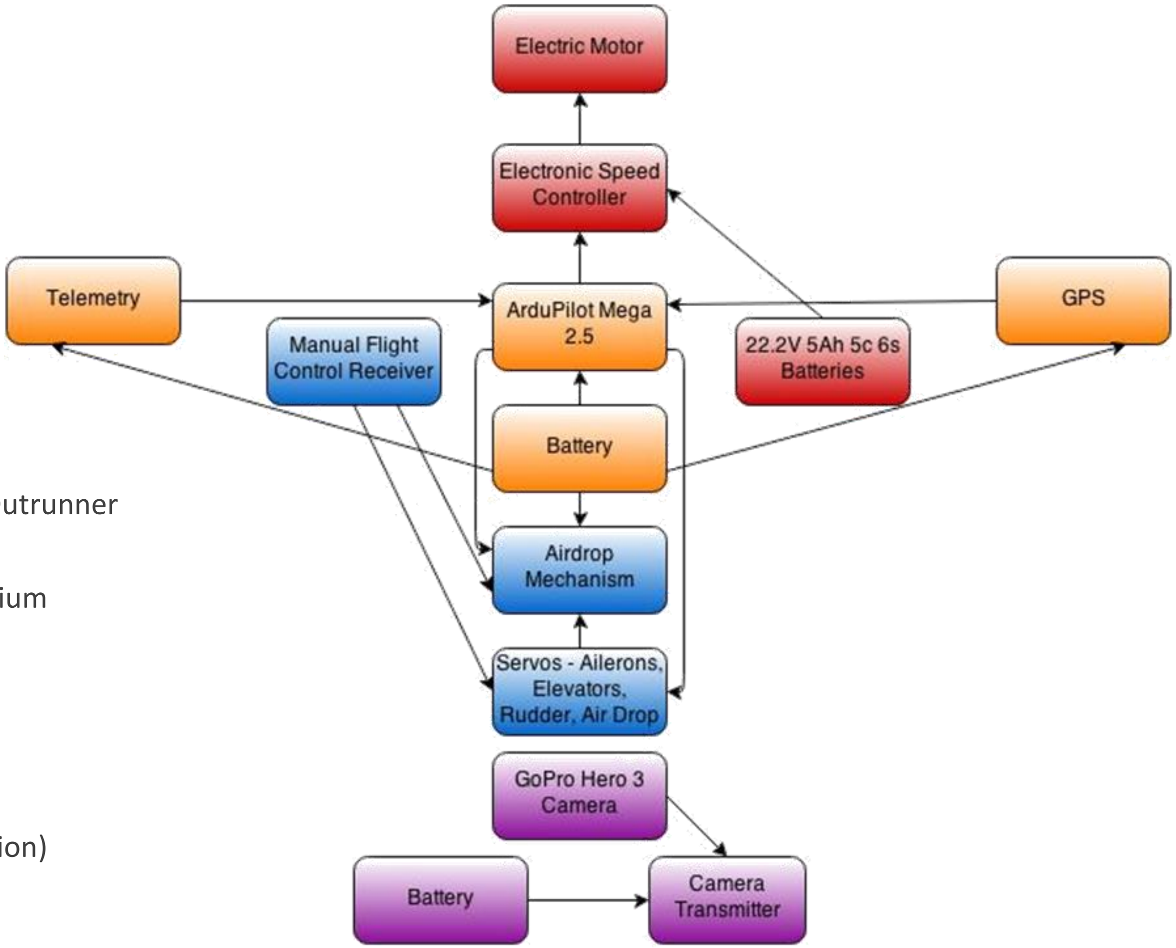
- Venom Li-Po (2x)
- Tenergy Ni-Mh

Electric Motor

- Model: .46 Brushless Outrunner
- RPM/Voltage: 600
- Battery Range: 4-6 Lithium Polymer
- Weight: $0.474lb$

Servos

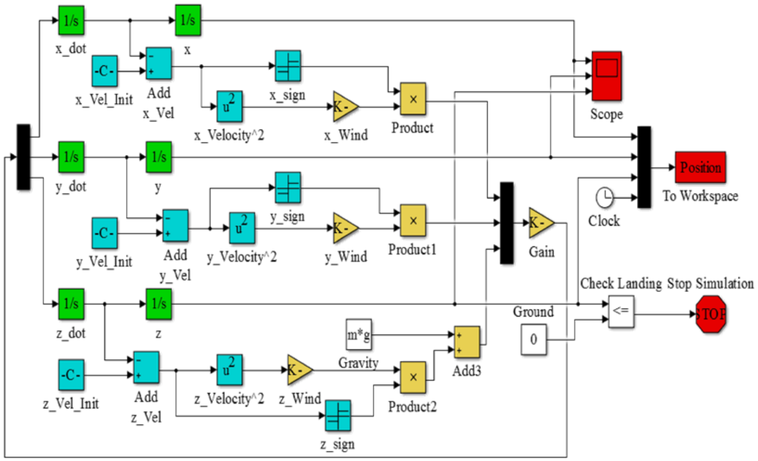
- Futaba S3004
- Futaba FP-S148 (Precision)

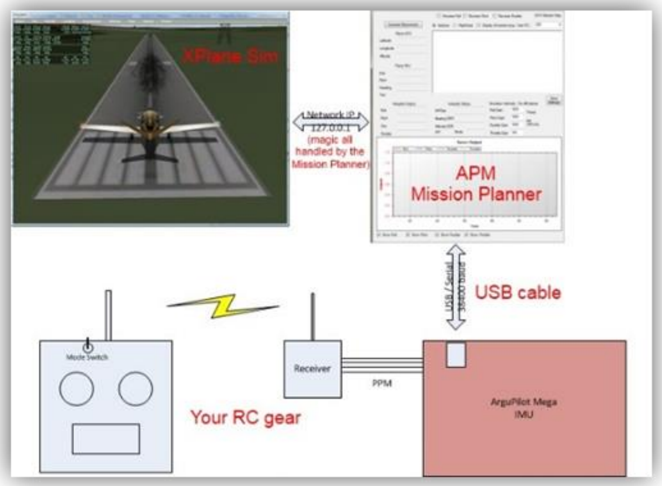


Simulations

Airdrop

- Analysis of payload dropped under given wind conditions performed in Simulink
- Considerations
  - Plane velocity (initial conditions) and wind speed under free fall
  - Payload mass and geometry
- Determination of impact coordinates
  - Used to create offset from release position





Hardware-in-the-Loop (HIL)

- Autopilot HIL simulation testing with X-Plane 10
  - Use of flight simulator to test autopilot scripts
  - Safe testing and debugging environment
  - Fully tested autonomous takeoff and landing

Test Flight – Mechanics

Set throws on all flight controls

- Ailerons: $25mm$
- Elevator: $20mm$
- Rudder: $35mm$

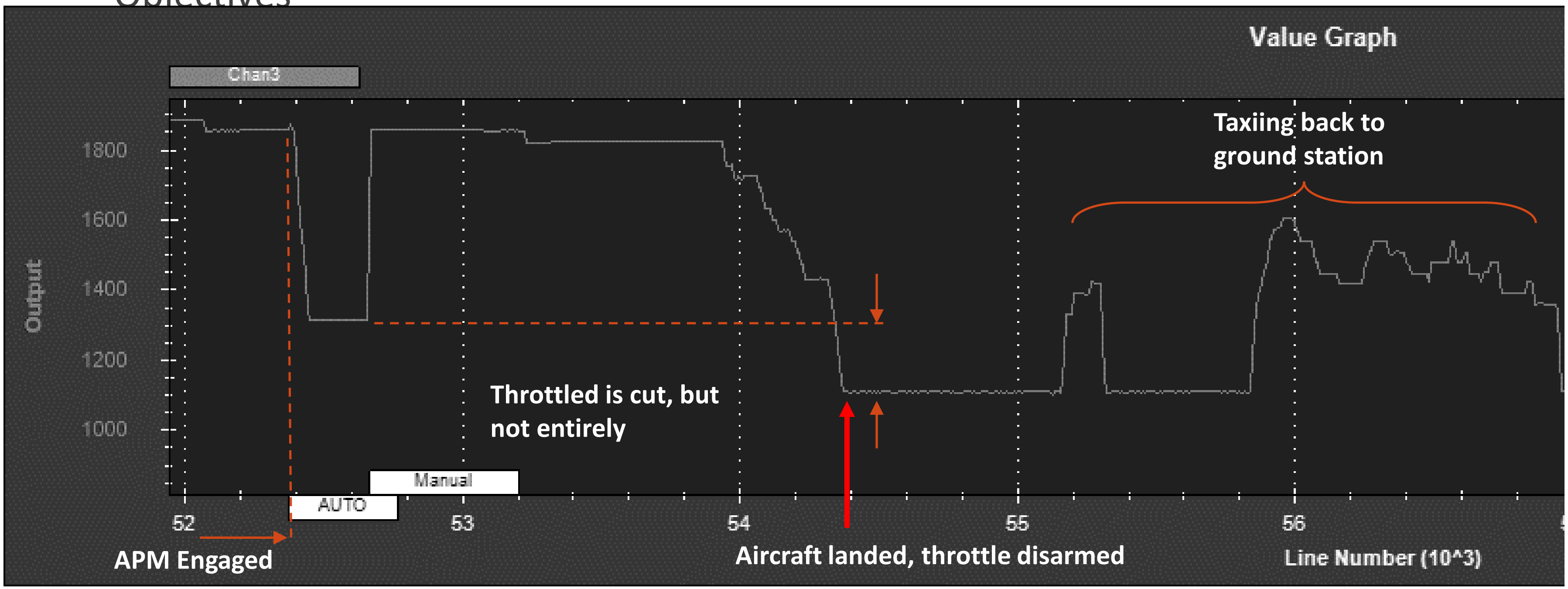
Adjusted location of batteries to move center of gravity to appropriate location

Results

- Airdrop servo failed pre-flight checks – not tested in-flight
- Electric motor provided sufficient power in manual mode
- Throws were set to high, require adjustment
- Need switches for power systems so that batteries and connections do not have to be constantly unplugged
- GPS mount came undone during nose dive

Test Flight - Autopilot

Objectives

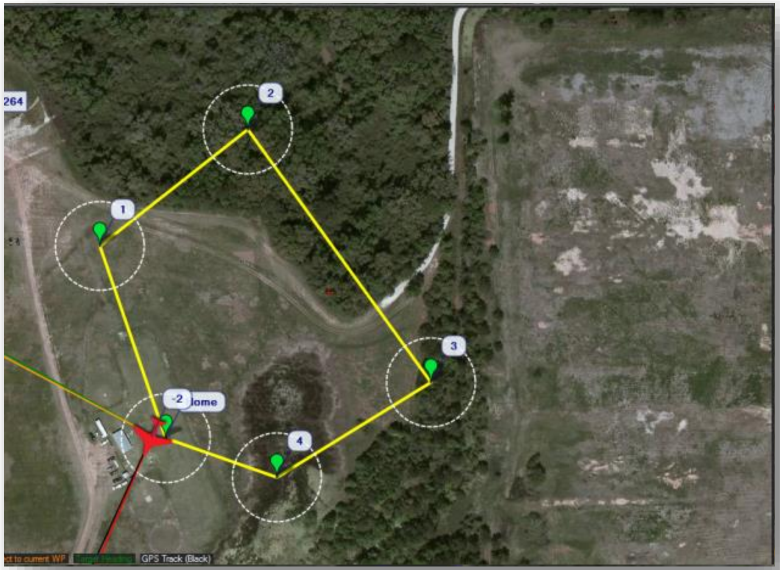


- Misconfiguration due to communication link error

Second Test Flight

Goals

- Autopilot
  - Stabilized flight
  - Autonomous navigation
- Manual payload release
- Collect target video
  - Used to test image analysis application



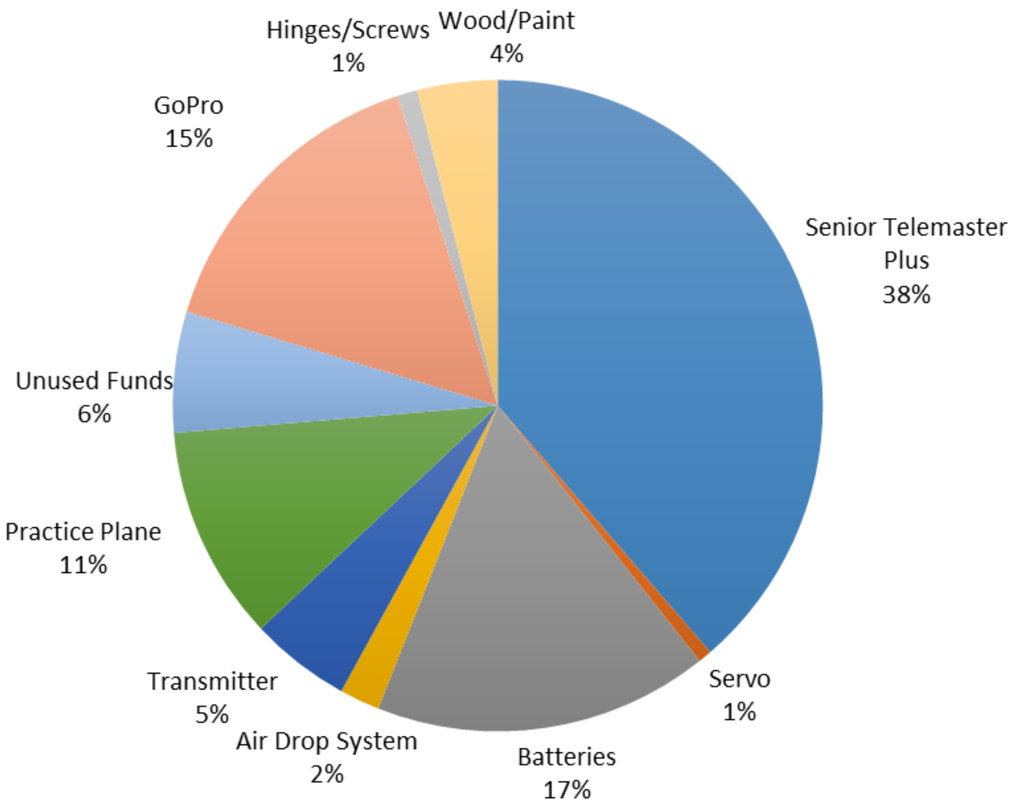
Results

- Autopilot
  - Stabilize mode – small elevation decline
  - Full auto – functioned flawlessly
- Airdrop was successful
- Image analysis
  - 50% identification of ground targets

Test Flight Video

Test Flight Video

Budget



$1,500 budget

$1,410 spent

$90 remaining

Safety Analysis

Operational risk

- Project
  - Autopilot software malfunction
  - Loss of communication
  - Pilot competency
  - Mechanical and structure failure
- Human safety
  - Aircraft propeller
    - High velocity, high torque
  - Batteries
    - Large capacity, fast discharge
  - Loss of control
    - Falling projectile hazards

- Safety Procedures
  - Pre-flight ops check
  - Motor physically disconnected from power source during setup and ground tests
  - Personal protective equipment (PPE)
  - Follow safe electrical wiring practices

Conclusion

Successfully engineered plane for competition

- Airdrop
- Autonomous navigation
- Target recognition using image analysis

Competed project under-budget

Achieved objectives according to schedule

Worked efficiently as a team

Acquired valuable multi-discipline design experience

Future Recommendations

Autonomous implementation
- Airdrop system
- Takeoff and landing

Focus on software
- Adjust team balance
  - More ECE students
  - Possible CS students

RC piloting experience
- Consult experts
- Provide training resources

Video stream quality
- Invest in fully digital HD streaming equipment

General Remarks

Special thanks

- Faculty
  - Dr. Amin
  - Dr. Frank
- Sponsor
  - Dr. Shih
- Technical Advisors
  - Dr. Yu
  - Dr. Alvi
- RC Pilot/Consultant
  - Robin Driscall
  - Dean Gonzalez
- Administration and Procurement
  - Mr. Cloos

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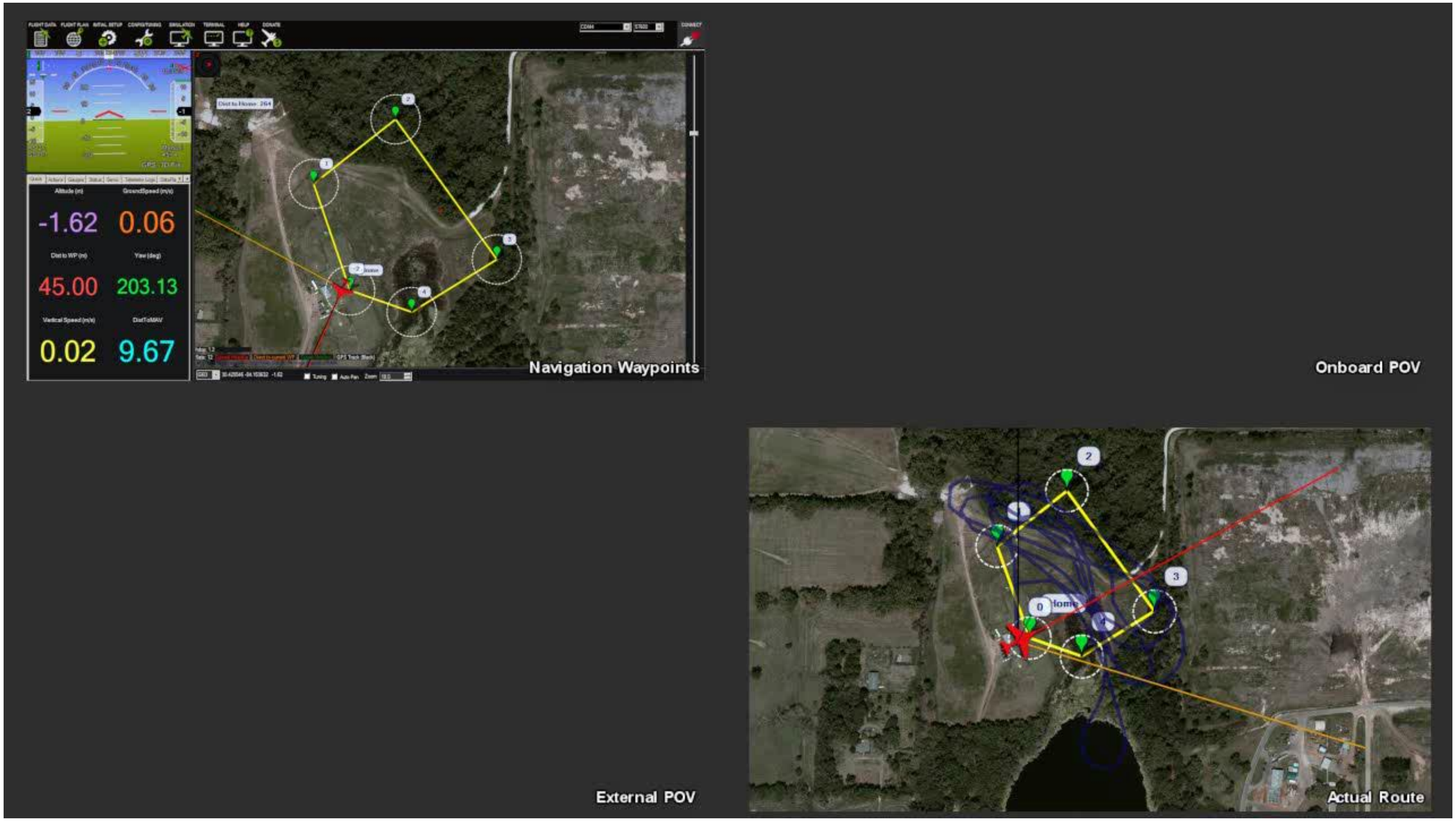
Questions?


-1.62
0.06
45.00
203.13
0.02
9.67
Navigation Waypoints
Onboard POV
External POV
Actual Route